# A STUDY OF GRASSHOPPER POPULATIONS IN COUNTRYSIDE STEWARDSHIP SCHEME FIELD MARGINS IN ESSEX

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## ABSTRACT

Countryside Stewardship Scheme field margins have been established over large parts of the UK since 1991 in an effort to improve the environmental quality of farmland. A small scale study of grasshopper populations of 6-m wide Countryside Stewardship Scheme grass margins on a lowland farm in Essex was undertaken to ascertain whether these margins were favourable habitats for grasshoppers in comparison with other agricultural sites. Grasshopper population densities were not significantly higher in 6-m grass margins than in intensively managed agricultural habitats. The abundance of grasshoppers and species richness/assemblage diversity were reduced in later years of the scheme agreement. The authors suggest that further research is needed into the effects of initial establishment, location and management of these field margins on grasshopper abundance.

## INTRODUCTION

Government agri-environmental initiatives such as the Countryside Stewardship Scheme are aimed at improving the environmental quality and biodiversity of agricultural areas (Smallshire & Cooke, 1999; Kleijn & Sutherland, 2003). However, it is not known whether such prescribed management techniques promote these aims or actually impede colonisation of grasslands by insects. A limited amount of research has been conducted on habitats created by field margins developed as part of the Countryside Stewardship Scheme and on increasing invertebrate abundance in long-term experimental plots reflecting the aims and objectives of agri-environmental policies (Haughton *et al.*, 1999; Meek *et al.*, 2002).

A study of butterfly populations on Countryside Stewardship Scheme grass margins has demonstrated that these artificial linear habitats are not favourable for species such as Large Skipper *Ochlodes venata* Bremer & Grey due to adverse management regimes and establishment of non-native aggressive grass species (Field, 2002; Field *et al.*, 2004 in press). However, a study of tenthredinid sawflies (Barker & Reynolds, 1999) found that margins lead to higher densities of larvae than cereal fields.

Orthoptera are an important invertebrate component of grassland ecosystems, particularly as prey for bird and spider species (Joern, 1986; Belovsky & Slade, 1993). However, Orthoptera on farmland have not been extensively studied in the UK. It has been thought that the abundance of grasshoppers is influenced by sward height, density and composition (Clarke, 1948; van Wingerden *et al.*, 1992; Gardiner *et al.*, 2002), although precise data on this subject in the UK are scarce.

The aim of this paper is to present the results of a small-scale study of grasshopper populations on 6-m Countryside Stewardship Scheme field margins on a lowland farm in Essex, and to assess whether these margins are favourable habitats for grasshoppers in comparison with other agricultural and conservation areas.

## Method

### Study sites

Nine study sites (A–I) were surveyed, encompassing a wide variety of habitats including 6-m Countryside Stewardship Scheme field margins, grazed pastures and hay meadows located on agricultural land at Writtle College, Chelmsford in Essex (Table 1; Figure 1). The approximate size of the College Estate is 210 hectares, mainly comprised of farmland and horticultural areas, with some designated conservation sites. A high proportion of the arable area is sown with winter cereals (wheat and barley). The estate extends over many different soil types, but most originate from glacial boulder clay and have variable pH (5.8–8.1) and high moisture content in winter (Neate, 1979). The Writtle area has a temperate climate with an annual mean air temperature of 10°C and total yearly rainfall of approximately 550 mm (Writtle College, 2003).

Sites B and D were 6-m Countryside Stewardship Scheme field margins established in 1996, the former using natural regeneration, the latter created from the existing grass ley. Field margin B was located on the northern edge of an arable field sown successively with winter beans and winter wheat during the study period. Site D extended along the eastern extremity of a field managed as grassland under the set-aside scheme. Both field margins were established on alluvial soils and were bordered by rivers which often flood in winter. The margins were cut after mid July in each year and the cuttings removed in accordance with Countryside Stewardship Scheme guidelines (MAFF, 2000).

A disused farm track situated on well drained glacial gravel was included in this study (Site I) as it represented a linear habitat not under Countryside Stewardship Scheme management. The track was used as an access route to arable fields until 1995 and was frequently traversed by vehicles thus establishing a short sward with sizeable patches of bare earth. However, since 1995 the track has had very infrequent vehicular usage. The track bordered arable fields on its northern and southern edges which were sown with winter beans, winter barley and winter wheat during the study period.

A range of intensively managed farmland habitats were also surveyed, allowing a comparison with grasshopper populations in linear field margins. These intensively

Table 1. Main characteristics of the study sites

| Site | Plot | Grid Reference | Dominant habitat type | Area ($m^2$) | Dominant species |
|---|---|---|---|---|---|
| A | S | TL669070 | Arable field | 100500 | *Hordeum* spp. |
| B | L | TL680073 | CSS grass field margin | 4500 | *Lolium perenne* |
| C | S | TL664067 | Lightly grazed horse pasture | 3750 | *L. perenne* |
| D | L | TL688071 | CSS grass field margin | 4320 | *L. perenne* |
| E | S | TL674068 | Heavily grazed cattle pasture | 10600 | *L. perenne* |
| F | L | TL672069 | Hay meadow | 11250 | *L. perenne* |
| G | S | TL675069 | Set-aside grassland | 30000 | *Phleum pratense* |
| H | S | TL663068 | Heavily grazed sheep pasture | 10100 | *L. perenne* |
| I | L | TL663073 | Disused farm track | 750 | *Agrostis stolonifera* |

S = standard plot (10 × 10 m).
L = linear plot (5 × 20 m).
CSS = Countryside Stewardship Scheme.

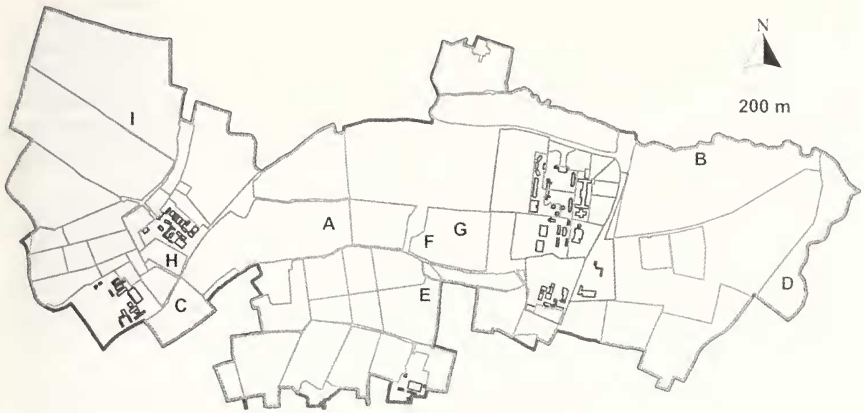


Fig. 1. Location of the study sites on the Writtle College Estate.

managed habitats included an arable field (Site A – winter barley) and heavily grazed pastures (Sites E and H), all of which received inorganic fertiliser applications during the study.

## Sampling method for grasshopper populations

The method used for surveying grasshoppers in this study is published in Gardiner *et al.* (2002). The size of the quadrats used in the survey was $4\,m^2$ ($2 \times 2\,m$). Ten quadrats were positioned at random in a $100\,m^2$ plot at each study site. The corners of each quadrat were marked using poles without the observer disturbing the grasshoppers within by casting shadows. Two types of plot were used: a standard $10 \times 10\,m$ plot and a plot of $5 \times 20\,m$ for linear grasslands such as field margins where it was impossible to accommodate the former plot. Each plot at the study sites was surveyed to ascertain grasshopper abundance and species richness once in July and once in August, in both 2000 and 2001. Only adult grasshoppers were recorded in this study, because during this life stage, identification can be confirmed without the need for capture of individuals (Richards & Waloff, 1954).

The numbers of adult individuals of each species were recorded by visual sighting in each quadrat. The vegetation of each quadrat was brushed with a pole to cause any grasshoppers present to jump (Richards & Waloff, 1954). This 'flushing' of grasshoppers was conducted in a standardised method ensuring coverage of the whole quadrat by moving from one edge to the other, sweeping the vegetation in an 180° arc. Only grasshoppers within the quadrat at the start of the sweep were recorded. One observer conducted all of the grasshopper surveys to minimise any recording error. The surveys were undertaken between 1045 and 1545 hours, if the air temperature was 17°C or above (Marshall & Haes, 1988; Pollard & Yates, 1993). Total and individual species densities per $m^2$ were calculated for each site by combining the data collected in both years.

### Statistical analysis of habitat preferences and assemblage diversity

Relationships between the densities per $m^2$ of each grasshopper species at each of the nine sites were tested using the Kruskal–Wallis multiple comparison statistic (Heath, 1995) to investigate habitat preferences. For ease of analysis, abundance data for each site were pooled for 2000 and 2001. Dunn's non-parametric procedure (Gardiner, 1997) was used to determine significant differences in grasshopper density between sites.

Species Diversity and Richness (Version 3.02) software (Pisces Conservation Ltd, IRC House, The Square, Pennington, Lymington, Hampshire) was used to analyse the assemblage diversity for each of the study sites. The Shannon–Wiener diversity Index (H′) (Kent & Coker, 1992) was calculated for each site using the total number of individuals recorded for each grasshopper species (2000 and 2001 data combined).

### Changes in grasshopper abundance and assemblage diversity during margin establishment

To study the colonisation of the two Countryside Stewardship Scheme margins by grasshoppers (Sites B and D), the authors surveyed the margins at three (1999), five (2001) and seven (2003) years after establishment, using the standard $2 \times 2$ m quadrat methodology outlined previously. Additionally, a control plot was established in a lightly grazed pasture (Site C) to determine how grasshopper populations fluctuated in the wider countryside. In all three years, grasshoppers were counted in at least 10 randomly located quadrats at each site. The Shannon–Wiener diversity Index (H′) was calculated for each of the sites in all three years of the agreement using the total number of individuals recorded for each grasshopper species.

## Results and Discussion

### Habitat preferences of grasshoppers

The most frequently observed acridid in this study was Lesser Marsh Grasshopper *Chorthippus albomarginatus* De Geer accounting for 69% of total sightings for 2000 and 2001 combined (219 observations). Meadow Grasshopper *Chorthippus parallelus* Zetterstedt and Field Grasshopper *Chorthippus brunneus* Thunberg were rarer on the College Estate with approximately 31% (98 observations) and 1% (1 observation) of all sightings respectively for 2000 and 2001 combined. *Chorthippus albomarginatus* is often found in inland areas beside rivers in flood meadows and wetlands in the UK (Haes & Harding, 1997) and this may explain its presence on Countryside Stewardship Scheme field margins at the study site (Table 2). *Chorthippus brunneus*, however, prefers dry habitats with sparse vegetation (Marshall & Haes, 1988) which are infrequent habitats at the study site.

All three grasshopper species were recorded at only one study site in 2000 and 2001 (lightly grazed pasture, Site C), whereas at five sites, which included both the Countryside Stewardship Scheme field margins (Table 2), two species (*C. albomarginatus* and *C. parallelus*) were recorded. *Chorthippus albomarginatus* was not recorded in intensively managed agricultural habitats such as arable fields (Site A) or heavily grazed pasture (Site H), suggesting that field margins may provide a valuable refuge for this species in areas of intensively managed farmland. Assemblage diversity in both field margin sites was higher than in two intensively managed habitats (Sites A and H; Table 2) indicating that these grass margins had a

Table 2. Adult density per $m^2$ of three *Chorthippus* species and assemblage diversity (H′) for 2000 and 2001 combined

| Site | Combined Density | *C. albomarginatus* | *C. brunneus* | *C. parallelus* | Diversity (H′) |
|---|---|---|---|---|---|
| I | 1.45 (232) | $1.08^{a}$ (173) | $0.00^{a}$ (0) | $0.37^{a}$ (59) | 0.57 |
| C | 0.35 (56) | $0.21^{b}$ (34) | $0.01^{a}$ (1) | $0.13^{b}$ (21) | 0.74 |
| F | 0.09 (14) | $0.03^{c}$ (4) | $0.00^{a}$ (0) | $0.06^{bc}$ (10) | 0.60 |
| B* | 0.06 (9) | $0.03^{c}$ (4) | $0.00^{a}$ (0) | $0.03^{c}$ (5) | 0.69 |
| D* | 0.03 (4) | $0.02^{c}$ (3) | $0.00^{a}$ (0) | $0.01^{c}$ (1) | 0.56 |
| E | 0.02 (2) | $0.01^{c}$ (1) | $0.00^{a}$ (0) | $0.01^{c}$ (1) | 0.69 |
| A | 0.01 (1) | $0.00^{c}$ (0) | $0.00^{a}$ (0) | $0.01^{c}$ (1) | 0.00 |
| G | 0.00 (0) | $0.00^{c}$ (0) | $0.00^{a}$ (0) | $0.00^{c}$ (0) | 0.00 |
| H | 0.00 (0) | $0.00^{c}$ (0) | $0.00^{a}$ (0) | $0.00^{c}$ (0) | 0.00 |

( ) values indicate sample size.
* Countryside Stewardship Scheme 6-m field margin.
Significant differences at $P<0.05$ between grasshopper densities within columns are denoted by different superscripts – Kruskal–Wallis test.

positive effect on the diversity of grasshoppers at the study site. However, due to the low numbers of grasshoppers recorded at some of the study sites, the species richness and assemblage diversity data should be viewed with some caution. A higher number of species and recorded individuals are required to fully elucidate the effect of field margins on grasshopper assemblage diversity.

Field margins had little impact on grasshopper density. For example, *C. albomarginatus* was more numerous on lightly grazed pasture (Site C) and the disused farm track (Site I) than on any of the other survey sites ($P<0.05$; Table 2). *Chorthippus albomarginatus* was recorded in very low numbers in the two grass field margins that were established in an effort to enhance farmland biodiversity in the area under the UK Government's Countryside Stewardship Scheme. However, densities of this species were not statistically different in these two field margins than in the intensively managed agricultural habitats such as Sites A and H.

Densities of *C. parallelus* were particularly low in intensively managed agricultural habitats such as Sites A and H, sites which were also not favoured by *C. albomarginatus* or *C. brunneus*. In a similar fashion to *C. albomarginatus*, densities of *C. parallelus* were not statistically different on the two Countryside Stewardship Scheme grass field margins than in the more intensively managed farmland sites such as heavily grazed pasture (Sites E and H) or arable fields (Site A). *Chorthippus brunneus* was absent from intensively managed pastures (Sites E and H) and Countryside Stewardship Scheme grass field margins in 2000 and 2001 (Sites B and D).

The two grass field margins in this study were established with funding from the UK Government's Countryside Stewardship Scheme. The aim of the Countryside Stewardship Scheme is to maintain and enhance wildlife and other landscape features (Smallshire & Cooke, 1999; Peach *et al.*, 2001). Uncultivated grass field margins have been created over large parts of Britain under such agri-environmental schemes. However, this study provides some evidence that grasshopper populations in these margins are no higher than in intensively managed agricultural land. This may be due to both field margins being situated adjacent to habitats (arable fields and set-aside grassland) which, in this study, had low grasshopper populations. Colonisation of margins in such isolated locations is therefore likely to be slow and it may take

many years for grasshoppers to attain large populations. The authors suggest that the large populations of both *C. albomarginatus* and *C. parallelus* at Sites C and I reflect the maturity of the grassland swards at these sites. Historical records show that both sites have had continuous grassland cover for at least 10 years allowing grasshoppers to colonise and sustain large populations.

Soil type and sward composition may also be important factors in the colonisation of field margins by grasshoppers. For example, both field margins were located on moist, nutrient rich, alluvial soils that promoted the growth of grass species such as Perennial Rye-grass *Lolium perenne* L. which dominated in both margins (Table 1). Gardiner *et al.* (2002) suggest that this grass species produces an unfavourable habitat for grasshoppers on fertile soils, perhaps because it forms a tall and dense sward with a 'cold' microclimate (van Wingerden *et al.*, 1991). Contrastingly, the disused farm track (Site I) which was located on well drained soil, had an abundance of the fine-leaved grass species, Creeping Bent *Agrostis stolonifera* L., which may provide a short, sparse sward with a favourable 'warm' microclimate, ideal for sustained grasshopper activity.

## Changes in grasshopper abundance and species richness/diversity during margin establishment

The Countryside Stewardship Scheme margins in this study were poor habitats for grasshoppers in comparison with other agricultural areas. There is also evidence from this study that the grasshopper populations declined in size over the course of the 10-year Countryside Stewardship Scheme agreement for both margins (Sites B and D; Figure 2). However, grasshopper populations in the lightly grazed control plot (Site C) actually increased.

In the 6-m margin established from a *L. perenne* grass ley (Site D) there were initially quite high grasshopper densities (three years after establishment). However, as the margins matured, in years five and seven of the agreement, grasshopper densities were much reduced. There was also a decline in species richness of grasshoppers and assemblage diversity in the margins. All three *Chorthippus* species were recorded three years after establishment in both margins, however, after seven years of the College Stewardship agreement only *C. parallelus* was recorded at Site B, whereas both *C. albomarginatus* and *C. parallelus* were observed at Site D. *Chorthippus brunneus* was not sighted in either margin seven years after establishment, perhaps due to the absence of short, open vegetation in the mature margins, that this species requires (Haes & Harding, 1997).

The decline in species richness was reflected by assemblage diversity which was high at both field margin sites three years after establishment (H′ values; Site B = 0.95, Site D = 0.87), but much lower seven years after establishment (H′ values; Site B = 0.00, Site D = 0.50). In contrast, assemblage diversity in the control area (Site C) increased (H′ values; year three of agreement = 0.43, year seven of agreement = 0.58).

It is suggested that the reduced populations of grasshoppers and reduced species richness/diversity in later years of the agreement were due to the annual cutting of the margins for hay in August. This management removed the entire grassland habitat in one event, leaving only a very short sward ( < 100 mm in height) that was unfavourable for adult grasshoppers (Gardiner *et al.*, 2002). Consequently, after cutting, grasshoppers may have dispersed into the surrounding areas in search of tall vegetation which provides more shelter from inclement weather and avian predation than the mown field margin.

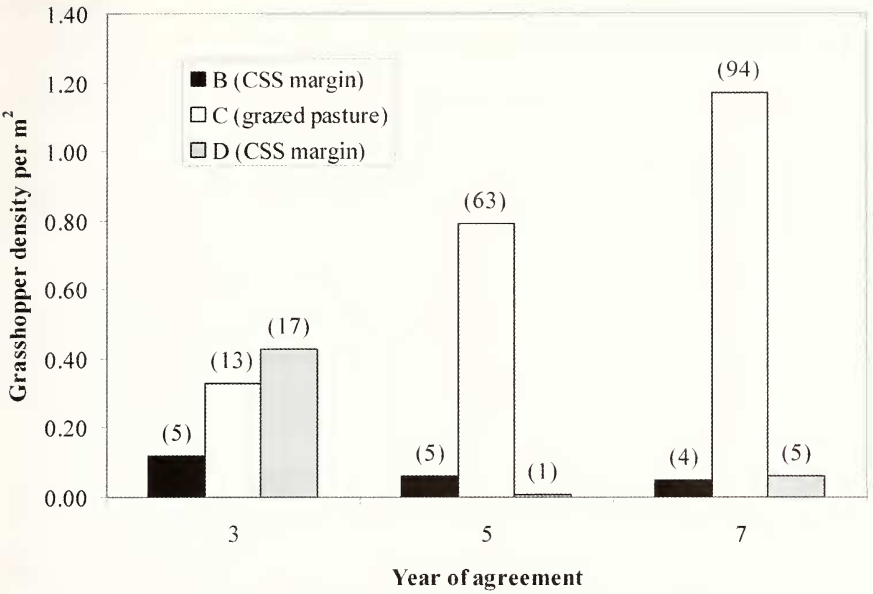


Fig. 2. Changes in total adult grasshopper density in two Countryside Stewardship Scheme (CSS) field margins (Sites B and D) and a control plot (Site C) over the course of the Writtle College CSS agreement. ( ) denotes sample size.

This small scale study suggests that 6-m Countryside Stewardship Scheme field margins may not be a particularly favourable habitat for grasshoppers, as population densities were no higher than in intensively managed agricultural areas (Table 2). However, other authors such as Barker & Reynolds (1999), suggest that field margins provide a valuable habitat for insects such as sawflies in intensively farmed areas. The number of insect species in field margins is likely to be high and management that favours grasshoppers may not be suitable for other insect groups. For example, grasshoppers prefer relatively short, open swards of 100–200 mm in height (Gardiner *et al.*, 2002), which may not be suitable for Heteroptera that are most numerous in taller swards (Morris, 1979). It is clear that field margins should possess a wide range of vegetation heights and floristic composition to satisfy the ecological requirements of as many different insect groups as possible.

Field margins have the potential to develop into a wide variety of grassland habitats depending on plant species composition, history of land use, location, soil type, and the seed mixture used during establishment. More quantitative research is therefore required to substantiate whether Countryside Stewardship Scheme field margins provide favourable habitats for grasshoppers.

## References

Barker, A. M. & Reynolds, C. J. M. 1999. The value of planted grass field margins as a habitat for sawflies and other chick-food insects. In: Boatman, N. D., Davies, D. H. K., Chaney, K., Feber, R., de Snoo, G. R. & Sparks, T. H. (eds) *Field margins and Buffer Zones: Ecology, management and policy*. Association of Applied Biologists, Warwick, pp. 109–116.

Belovksy, G. E. & Slade, J. B. 1993. The role of vertebrate and invertebrate predators in a grasshopper community. *Oikos* **68**: 193–201.

Clarke, E. J. 1948. Studies in the ecology of British grasshoppers. *Transactions of the Royal Entomological Society of London* **99**: 173–222.

Field, R. G. 2002. *A Study of Butterflies on Farmland.* Unpublished PhD Thesis, University of Essex, Colchester.

Field, R. G., Gardiner, T., Mason, C. F. & Hill, J. 2004 in press. Agri-environment schemes and butterflies: the utilisation of six metre arable field margins. *Biodiversity & Conservation.*

Gardiner, T., Pye, M., Field, R. & Hill, J. 2002. The influence of sward height and vegetation composition in determining the habitat preferences of three *Chorthippus* species (Orthoptera: Acrididae) in Chelmsford, Essex, UK. *Journal of Orthoptera Research* **11**: 207–213.

Gardiner, W. P. 1997. *Statistics for the Biosciences.* Prentice Hall, Hemel Hempstead.

Haes, E. C. M. & Harding, P. T. 1997. *Atlas of Grasshoppers, Crickets and Allied Insects in Britain and Ireland.* The Stationery Office, London.

Haughton, A. J., Bell, J. R., Gates, S., Johnson, P. J., Macdonald, D. W., Tattersall, F. H. & Hart, B. H. 1999. Methods of increasing invertebrate abundance within field margins. In: Boatman, N. D., Davies, D. H. K., Chaney, K., Feber, R., de Snoo, G. R. & Sparks, T. H. (eds) *Field Margins and Buffer Zones: Ecology, management and policy.* Association of Applied Biologists, Warwick, pp. 163–170.

Heath, D. 1995. *An Introduction to Experimental Design and Statistics for Biology.* UCL Press, London.

Joern, A. 1986. Experimental study of avian predation on coexisting grasshopper populations (Orthoptera: Acrididae) in a sandhills grassland *Oikos* **46**: 243–249.

Kent, M. & Coker, P. 1992. *Vegetation Description and Analysis: A practical approach.* John Wiley & Sons, Chichester.

Kleijn, D. & Sutherland, W. J. 2003. How effective are European agri-environment schemes in conserving and promoting biodiversity? *Journal of Applied Ecology* **40**: 947–969.

MAFF 2000. *The Countryside Stewardship Agreement: Information and how to apply.* MAFF, London.

Marshall, J. A. & Haes, E. C. M. 1988. *Grasshoppers and Allied Insects of Great Britain and Ireland.* Harley Books, Colchester.

Meek, B., Loxton, D., Sparks, T., Pywell, R., Pickett, H. & Nowakowski, M. 2002. The effect of arable field margin composition on invertebrate biodiversity. *Biological Conservation* **106**: 259–271.

Morris, M. G. 1979. Responses of grassland invertebrates to management by cutting II. Heteroptera. *Journal of Applied Ecology* **16**: 417–432.

Neate, D. J. M. 1979. *Writtle Agricultural College Wildlife and Landscape Survey: Report and recommendations.* Writtle College, Chelmsford.

Peach, W. J., Lovett, L. J., Wotton, S. R. & Jeffs, C. 2001. Countryside stewardship delivers cirl buntings (*Emberiza cirlus*) in Devon, UK. *Biological Conservation* **101**: 361–373.

Pollard, E. & Yates, T. J. 1993. *Monitoring Butterflies for Ecology and Conservation.* Chapman & Hall, London.

Richards, O. W. & Waloff, N. 1954. Studies on the biology and population dynamics of British grasshoppers. *Anti-Locust Bulletin* **17**: 1–182.

Smallshire, D. & Cooke, A. I. 1999. Field margins in UK agri-environment schemes. In: Boatman, N. D., Davies, D. H. K., Chaney, K., Feber, R., de Snoo, G. R. & Sparks, T. H. (eds) *Field Margins and Buffer Zones: Ecology, management and policy.* Association of Applied Biologists, Warwick, pp. 19–28.

van Wingerden, W. K. R. E., Musters, J. C. M. & Maaskamp, F. I. M. 1991. The influence of temperature on the duration of egg development in west European grasshoppers (Orthoptera: Acrididae). *Oecologia* **87**: 417–423.

van Wingerden, W. K. R. E., van Kreveld, A. R. & Bongers, W. 1992. Analysis of species composition and abundance of grasshoppers (Orth., Acrididae) in natural and fertilized grasslands. *Journal of Applied Entomology* **113**: 138–152.

Writtle College 2003. *Writtle College Annual Weather Report 2003.* Writtle College, Chelmsford.